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Novel Communications and Hearing Protection for Helmet Systems: Communications Earplug
~~(Reprint)~~

By

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NOVEL COMMUNICATIONS AND HEARING PROTECTION FOR HELMET SYSTEMS: COMMUNICATIONS EARPLUG

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Abstract

Communications and hearing protection are usually necessary for personnel involved in Army operations. Aircraft and ground vehicles produce noise levels in excess of the limits defined in current hearing conservation standards. Hearing protection and communications elements of most helmets constitute a significant portion of the weight of standard helmets. Further, performance of most helmets is marginal with respect to speech intelligibility and hearing protection. Some noise environments require that earplugs be worn in combination with the helmet protector in order to achieve adequate protection. The communications earplug (CEP) consists of a high quality earphone coupled with an earplug protector. Results of laboratory and field tests have demonstrated the effectiveness of this device. Speech intelligibility of the CEP in high noise environments is as good or better than any other available communications/ protector. Improvements in sound attenuation when worn in combination with the earcup allow for maximum time within any Army noise environment. The CEP is comfortable over a period of several hours and, in its current configuration, is considered highly acceptable by seasoned Army aviators and crewmembers. The CEP demonstrates significant improvements in speech intelligibility for the hearing impaired as well as normal hearing individuals. The weight of the system is less than 15 grams.

Introduction

Helmets used by today's military aviator and combat vehicle crewman are an evolutionary product of many years of the designer's attempt to meet goals and requirements of combat developers. Initial influences forcing the helmet design were to provide protection from the elements. Equipment such as microphones and receivers were added to the helmet to enable communications where it was necessary. The need to communicate was probably the impetus for sound attenuation in order to improve signal to noise for improving the communications capability of the aviator. During the 50s and 60s, improvements

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in hearing protection capability of helmets became a requirement as we began to understand the military noise environment and its effect on hearing and communications. The development of the sound protective helmets (SPHs), the SPH-4 in the late 1960s, was probably the first design directed primarily toward the protection of hearing. This was followed closely by the development of the DH-132 Combat Vehicle Crewman (CVC) helmet which, likewise, incorporated enhancements in hearing protection. The specification for the SPH-4 included significant improvements in impact protective properties, in addition to imposing severe limits on overall weight of the helmet in order to enhance the survivability of helicopter crewmen involved in accidents.

Since the advent of night vision goggles (NVGs), heads up displays (HUDs), and other useful apparatus, the helmet has become a mounting platform for almost any conceivable device or tool that may be used to improve warfighting performance of the aviator. Using the helmet in this manner provides the developer with increased latitude in overcoming human factors interface problems and provides the aviator with significant enhancements to mission performance. The obvious drawback is overloading the aviator, placing her/him in a vulnerable situation when considering health risk from extended use, or immediate risk in the event of an mishap.

Discussion

Noise levels inside military helicopters generally exceed noise exposure limits established by DOD Instruction 6055.12, "Hearing Conservation." Noise levels in helicopters with higher load capacities are extremely high and sometimes exceed the helmet's capability to provide adequate hearing protection for crewmembers. Voice communication also is compromised by the increased noise because of reduced speech signal-to-noise ratio reaching the ear. Due to the insidious nature, hearing loss can overcome some individuals before they are aware of the health effect.

There are three fundamental classifications of hearing protective devices. Inserts or earplugs are inserted directly into the earcanal creating a barrier between the user's internal ear and the outside ambient noise environment. Circumaural hearing protectors are enclosures that encircle the pinna and are held tightly to the head of the wearer. The canal cap is a supra-aural protector that covers the external earcanal opening. There is usually a soft cushion between the head of the user and the earcup of canal cap that serves as an interface to improve comfort. The efficiency of the barrier depends on the interface of the earplug to earcanal or cushion to the head and the attenuation characteristic of the earplug, canal cap, or earcup. There is a fine balance at the interface, too tight or rigid can cause discomfort for the user, and too loose can allow too much sound energy through to the ear.

In the recent past, earplugs worn in addition to the helmet have provided adequate hearing protection for most Army noise environments. However, sound attenuation of the speech signal by the earplug compounds problems associated with communications capability. Currently, several methods of improving speech intelligibility and hearing protection are in development and are being operationally tested with some limited fielding into military operations. Active noise reduction (ANR) techniques have been shown to improve both hearing protection and

speech intelligibility. The technique provides exceptionally low frequency hearing protection, but it does little or nothing to improve protection for frequencies above 800 Hertz. Studies conducted at the U.S. Army Aeromedical Research Laboratory (USAARL) show ANR does improve speech intelligibility when worn alone, but both hearing protection and speech intelligibility are degraded when worn with ancillary equipment such as spectacles and CB mask. Aircraft modification, system cost, lateral impact, weight, and others factors should be evaluated carefully when considering the use of ANR in the helicopter environment. The CEP is a device that incorporates a miniature earphone with foam earplug and can be worn in combination with the aviator's helmet. The CEP requires an additional step in the donning process and for the non-earplug user, it does require time to accommodate to the addition of something in the earcanal. Calculations show the CEP provides adequate hearing protection for 8 hours of duty even in the high noise levels found in the H-53. The device also provides voice communication intelligibility that approaches asymptotic limits near 100 percent in those high noise environments.

The weight of the helmet is critical when considering the ultimate effectiveness when used in today's military environment. Individuals riding in aircraft or vehicles are subjected to significant forces on the head and neck system because of head supported mass. These forces become critical during high accelerations of the head caused by rough terrain, direction changes to evade and escape, or mishaps. The weight of the communications system portion of the helmet is about 25 percent of the total. Table 1 shows the weight of each communications component of the CEP, the HGU-56/P and an ANR earcup system. Considering the limit in terms of weight savings, use of the CEP as a complete replacement of the earcup system would result in saving about 198 grams for the HGU-56/P or about 290 grams for the ANR communications system.

Table 1.
Weight of the CEP and helmet communications components.

Item	Weight (g)
CEP with HGU-56/P interface cable and blown-air port adapter	18.8
CEP	8.0
Interface cable	5.0
Blown-air port adapter	5.8
HGU-56/P earcup with foam inserts, 2990 earseal, and earphone (model 996) X 2	215.0
HGU-56/P earcup with foam inserts and 2990 earseal X 2	175.0
Earphone, model 996	19.8
ANR earcup and earseal X 2	308.4

It is our opinion that the earcup performs a significant role in providing comfort for the user and for acceptability of the helmet system as a protective device and mounting platform. The earcup is a very useful feature of the helmet system in maintaining stability of the helmet/head relationship that would otherwise result in significant degradation of the visual performance of

the user when using displayed image systems. The earcup also acts to isolate the pinna from pressure of the helmet that may reduce the cause of discomfort to the user. The CEP will provide the major portion of hearing protection and the voice communications signals while the earcup will supplement the protection, resulting in adequate protection for any noise environment found in Army aviation.

A comparison of sound attenuation and hearing protection of the HGU-56/P helmet with the ANR and the CEP was conducted during 1996. The sound attenuation provided by the CEP and HGU-56/P helmets was measured using the ANSI S12.6 (REAT) procedure. The sound attenuation provided by the ANR helmet was measured using the MIL-STD-912 (PEAT) procedure. The devices were worn alone and in combination with spectacles and CB mask. The mean and standard deviation of the REAT attenuation measurement results for each of the test frequencies are shown in tables 2 and 3.

Generally, the standard deviations of the attenuation measures for REAT and PEAT are greater while wearing spectacles or CB mask than when the device is worn alone, while the sound attenuation mean values are greater when wearing the helmet alone. Head shape and fit of the device on the subject accounts for most of the variability of the attenuation measurement. It is important to note that the mean values are maintained at a higher level when wearing the ancillary devices than is the case for the HGU-56/P with or without ANR. Exposure calculations shown in table 4 demonstrate the effects of using spectacles or CB mask on the hearing protection capability of the CEP, ANR and HGU-56/P. The effects of using CB mask removes any hearing protection advantage the ANR1 device has over the HGU-56/P but does little to affect the performance of the CEP.

Table 2.
Real-ear attenuation characteristics of the hearing protectors.

		Frequency in hertz								
Device		**125**	**250**	**500**	**1000**	**2000**	**3150**	**4000**	**6300**	**8000**
HGU-56/P	Mean	18.0	19.2	22.7	33.3	31.7	40.4	42.5	43.8	43.4
	S. D.	3.5	3.2	3.5	6.0	4.6	5.0	4.1	6.1	5.8
HGU-56/P	Mean	29.1	26.0	33.0	30.6	40.1	50.2	55.6	54.1	53.5
w/CEP	S. D.	6.2	6.6	6.4	3.9	3.9	4.4	6.7	5.7	5.7

Table 3.
Physical-ear attenuation characteristics of ANR1 hearing protectors.

		Frequency in hertz								
Device		**125**	**250**	**500**	**1000**	**2000**	**3150**	**4000**	**6300**	**8000**
ANR1	Mean	21.2	31.2	29.7	34.4	39.9	43.7	47.7	48.8	48.8
	S.D.	4.9	4.9	2.5	3.8	2.5	1.5	2.6	1.6	3.2

Table 4.
Devices shown in ascending order of mean EEL in dBA for CH-47C noise.
Significant differences are shown, using letters to indicate mean levels.

Alone			Spectacles			CB Mask		
ANR1	73.6	a	CEP	75.7	a	CEP	75.8	a
CEP	75.2	a	ANR1	76.6	a	ANR1	92.1	b
HGU-56/P	82.0	b	HGU-56/P	86.7	b	HGU-56/P	96.1	b

Table 5 shows results of speech intelligibility tests of the helmets while wearing the same combination of ancillary devices. The speech intelligibility tests were conducted in an ambient noise environment of 105 dBA, which simulated the UH-60 helicopter flying at 120 knots. The results clearly show degraded speech intelligibility for the circumaural devices when combining spectacles or CB mask. During the course of the data collection, the circumaural devices were determined to provide inadequate protection for the subjects performing the test. Ambient noise levels were reduced 10 dB, 95 dBA, for the circumaural conditions to ensure adequate protection was available. However, the CEP condition was assessed at the 105 dBA ambient noise level for the CB mask condition. Most certainly, the difference in intelligibility between the CEP and the circumaural devices would be even greater than indicated in table 5.

Table 5.
Speech intelligibility hearing protectors worn alone, with CB mask, and with spectacles at constant speech level.

Test condition		**HGU-56/P**	**ANR1**	**CEP with HGU-56/P**
Alone	Mean	57	93	89
	S.D.	15.2	3.6	7.6
Spectacles	Mean	38	87	89
	S.D.	20.7	10.0	5.4
CB mask	Mean	39*	75*	84
	S.D.	24.4	23.3	12.1

*Ambient noise decreased 10 dB

Operational tests were conducted on the same devices with 39 aviators from four operational Army units. Each aviator used each of the devices for about 1 week and reported their subjective assessments of rank order of the devices in areas of comfort, speech clarity, sound reduction, and ease of use. These results of the assessment are shown in table 6 along with their subjective evaluation of the overall preference among the devices. Preference was shown to be in favor of the CEP even though donning/ doffing and comfort were scored at slightly lower levels.

Table 6.
Mean results of operational assessment. Rank ordered for 1="BEST" to 4="Worst."

Test device	Speech clarity	Noise reduction	Donning	Comfort	Outside sounds	Stability	Preference (Percent)
HGU-56/P	3.6	3.6	1.4	2.2	3.4	2.4	6
ANR1	2	2	2.4	2.2	2.6	2.4	30
CEP	1.6	1.7	3.3	2.6	1.2	2.5	58

A study comparing the CEP and the HGU-84 using Navy and Marine Corp aviators assigned at Quantico, VA, was accomplished over a 4-month period. A preference questionnaire was used to measure the volunteer's assessment of the CEP when compared to their personal helmet. The areas of interest were comfort, compatibility, communications performance, utility, and overall value added as assessed by each of the individual volunteers.

The rating scale was based on comparisons between the CEP and the helmet normally used by the volunteer with the midpoint (4) indicating no difference between the two. A rating of 7 indicated the user's highest CEP preference value while a 1 indicated the user's highest helmet preference value.

7	6	5	4	3	2	1
Significantly better	Moderately better	Slightly better	Same	Slightly worse	Moderately worse	Significantly worse

Results of the questionnaire responses were analyzed to determine the overall acceptability of the CEP for use in the H-53 missions when compared to the HGU-84 helmet. Table 7 shows results of questionnaires administered at the mid-point of the study and at the end of the study. For most of the questions, results showed slightly stronger preference for the CEP at the end of the study, indicating users found the CEP more acceptable with continued use. The fit and comfort of the CEP were judged to be the same as their standard helmet, indicating the perceived potential for discomfort was not realized by the user after 4 months of use. There was a difference in favor of the standard helmet in the donning/doffing process because of the extra step required to install the CEP. (It is the author's opinion that the user will become more proficient in the procedure with continued use of the CEP. Proper planning of events that take place in the donning process will limit or eliminate problems for even the most time critical mission start.) All of the noise reduction and speech clarity responses indicated a strong preference for the CEP over the standard helmet.

Table 7.
Results of midpoint and final questionnaire assessments (15 subjects).

	Midpoint	Final
Average number of flight-hours using CEP	30.5	40.7
Fit and comfort of CEP	4.2	4.1
Donning/doffing	3.5	3.5
ICS clarity	6.3	6.5
Radio communications clarity	6.3	6.6
Gender clarity (male)	6.1	6.6
Gender clarity (female)	6.0	6.6
Overall clarity	6.3	6.6
Noise reduction	6.3	6.4
Ability to hear warning signals	6.0	6.6
Ability to hear environmental sounds	4.1	4.1
Overall value of CEP	6.1	6.3

Table 8 shows several factors that are very important and should be reviewed when considering techniques that are directed toward improved hearing protection and speech intelligibility of helmet systems. Considerations of these factors are necessary for health, safety and performance of the aviator during flying duties. While the list is not all-inclusive, it does provide a starting point for the helmet developer.

Table 8.
Factors for consideration during the selection process.

FACTOR	ANR	CEP
Cost:	$450.00-$1750.00	<$100.00
Added weight:	(90 to 312 gm)	(-28 to 11 gm)
Aircraft modification cost:	$1000-$5000	Not required
Compatibility:	Reduced performance	Unaffected

Conclusions

ANR and CEP are viable approaches to improving aviator auditory performance while providing adequate hearing protection for Army noise environments. Both systems are far along in their respective development process and show promise for near term fielding. Cost of aircraft modification, helmet system cost, logistics, and reliability should be evaluated carefully when considering the use of ANR or CEP in the helicopter environment. The CEP system is lightweight, cost effective, and does not require modification of the aircraft wiring since the earphone element is of dynamic design. It is the author's opinion that the CEP approach

provides the best solution for all aspects of hearing protection, auditory performance and many of the other areas of consideration.

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